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(54) Atomizer

(57) An atomizer (10) includes a fluid mixing sonic cavitation chamber (12) provided with a first fluid inlet (26) to direct fluid within the chamber along the longitudinal axis of the chamber and a second fluid inlet (30) to direct fluid within the chamber and generate a fluid vortex around the longitudinal fluid flow, the chamber further including a deflector plate (34) positioned in the proximity of the first fluid inlet so as to deflect a portion of the longitudinal fluid flow into the vortex flow. The atomizer includes a second mixing chamber (14) with a restriction orifice (18) between the chambers and a discharge restriction orifice (20) whereby the fluids are subjected to alternating expansions and restrictions before exiting the mixing device in a uniformly mixed or dispersed state.

FIG. 1

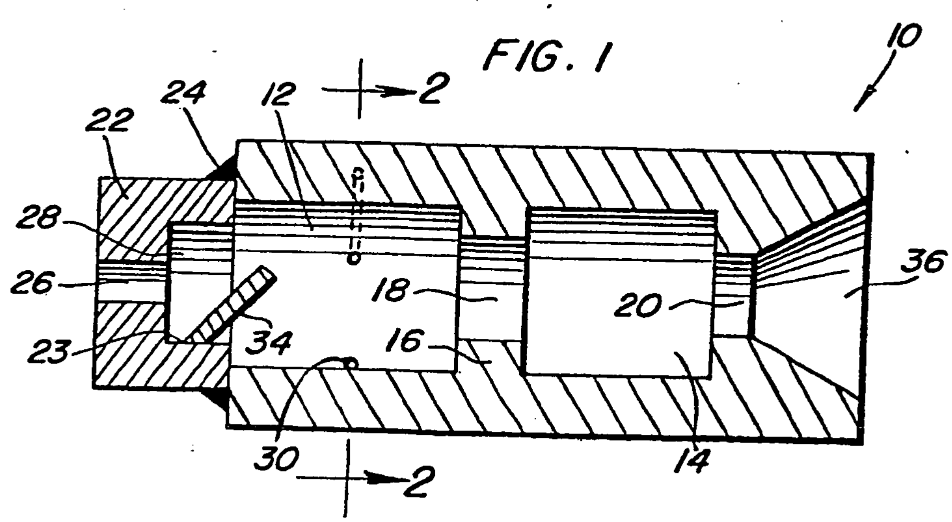

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FIG. 1

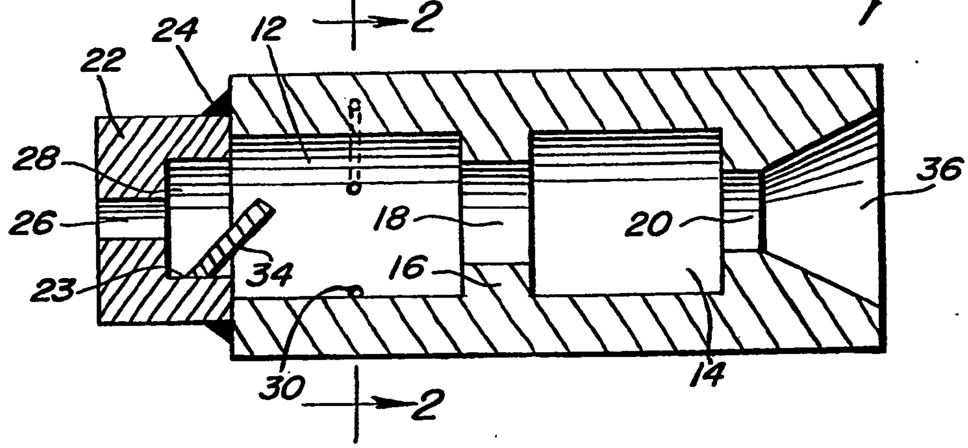


FIG. 4

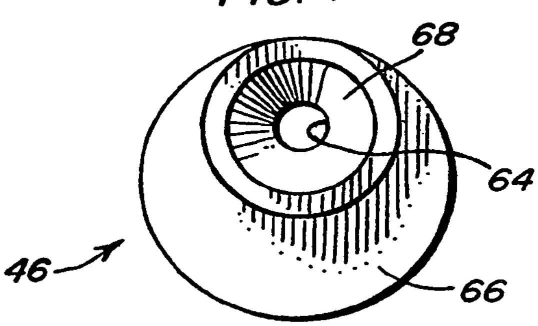


FIG. 2

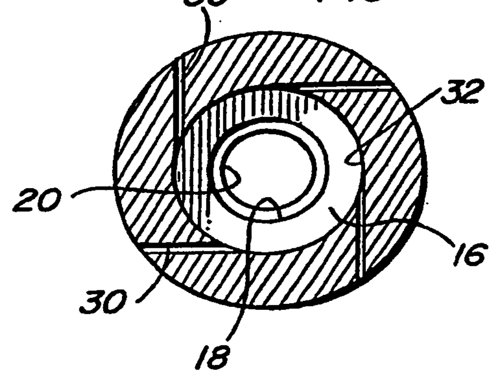
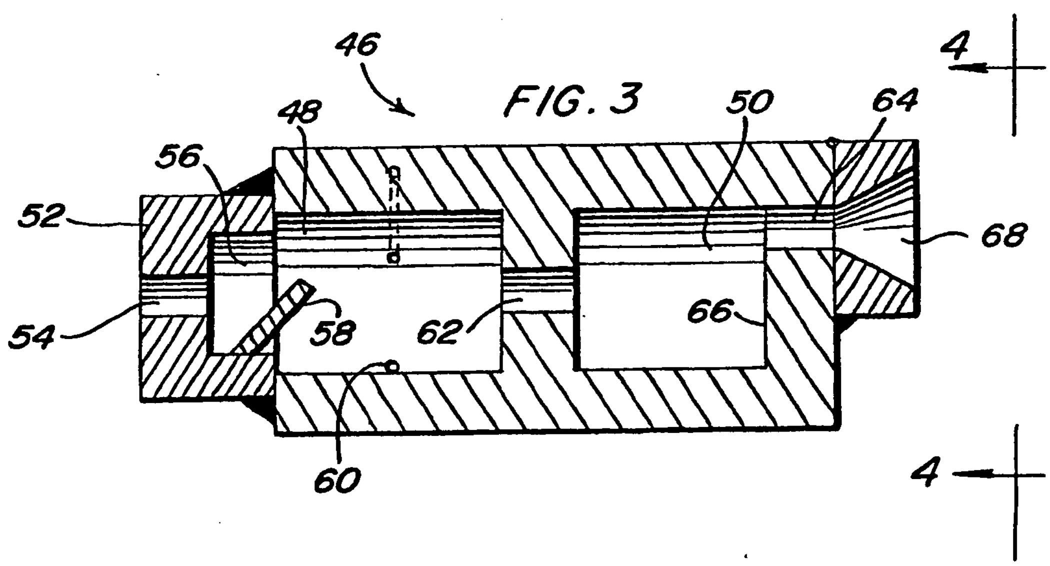


FIG. 3



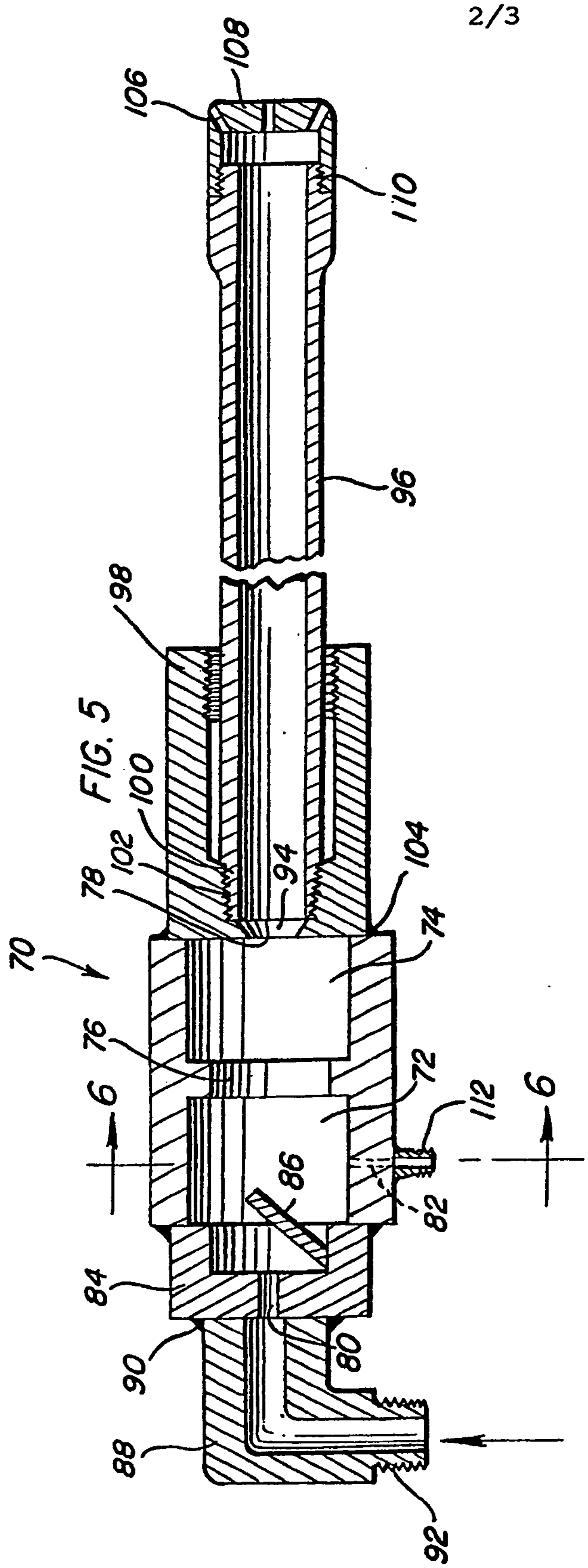


FIG. 5
70
106
108
110
96
98
100
102
78
94
104
74
76
72
6
6
112
86
82
84
90
80
88
92

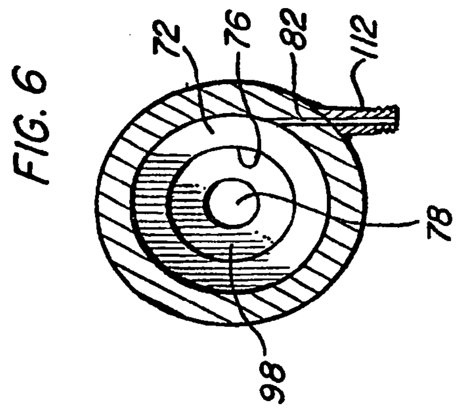


FIG. 6
72
76
82
112
78
98

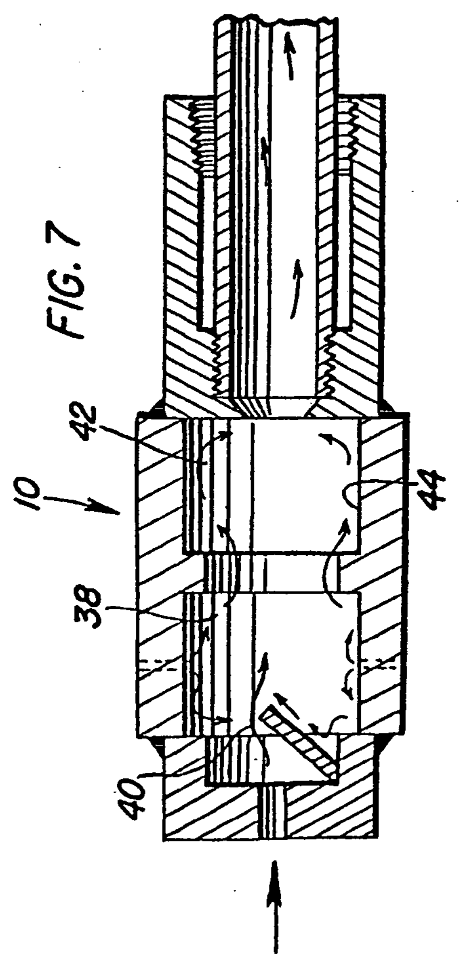


FIG. 7
10
42
44
38
40

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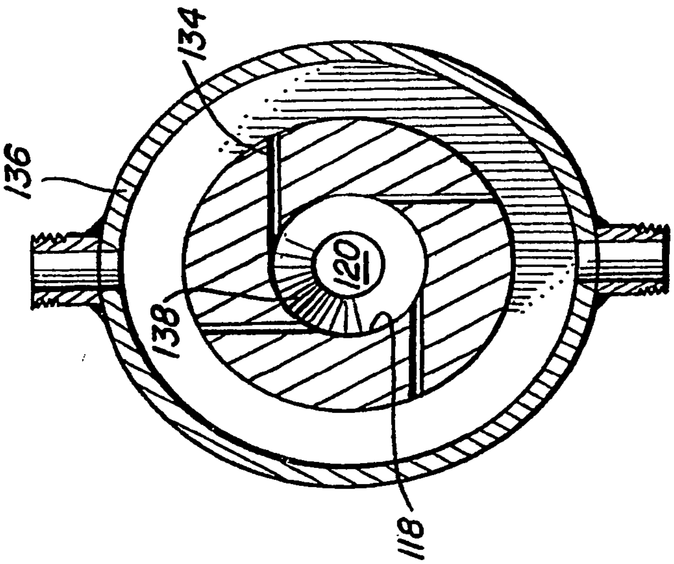

FIG. 9

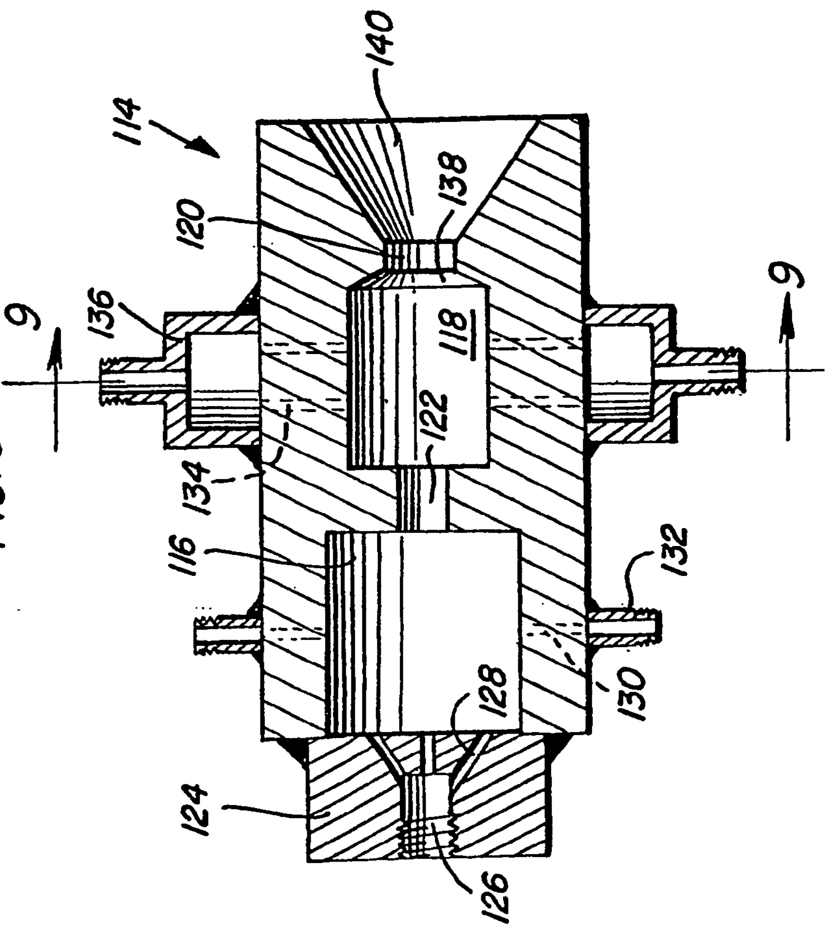

FIG. 8

SPECIFICATION
Atomizer

This invention relates generally to fluid mixing devices and, more particularly, to an atomizer, aerator, nebulizer or the like which entrains liquids in a gas stream, such as for use in feeding combustion chambers with combustible fluids.

Many prior art structures for atomizing fluids have utilized some form of sonic energy in an attempt to obtain complete atomization of the liquid as well as a control of the droplet size. Such attempts have included the use of structures which accelerate the entraining gas to supersonic velocities within a nozzle. To achieve supersonic flow it has been necessary in the past to establish a large pressure drop from the inlet to the outlet of the nozzle and to include resonators positioned beyond the outlet of the supersonic nozzle or a resonating sphere in the diverging section of the supersonic nozzle. U.S. patent specification No. 4,189,101 describes supersonic flow being produced without the requirement of external resonators or internal spheres by means of efficient gas vortex generation. The vortex movement of the gas is produced by the use of a bluff body such as a frustrum or flat disk which imparts rotational motion to the gas in the flow passage, the bluff body being located in the flow passage between the inlet and the outlet. Still other attempts at producing sonic gas velocities have used a converging-diverging nozzle structure so as to create a sonic pressure wave output. Such structures must be carefully constructed in order to obtain the sonic speeds. Examples of such structures are described in U.S. patent specifications Nos. 3,774,846 and 3,230,924.

Other atomizing devices have been structured to create sonic vibrations in order to overcome the internal surface tension of the liquid being atomized so as to break the liquid into a plurality of droplets of finely controlled size. Such devices create sonic vibrations in surfaces on which the liquid makes contact as the liquid passes through the device. Such sonic vibrations are produced by piezo electric transducers and rotating piezo electric transducers which vibrate wall or tubular resonators, and mechanically vibrated rod, tube or wall resonators. Examples of such devices are shown in U.S. patent specifications Nos. 3,474,967, 4,034,025 and 4,166,577.

While these prior art devices may have been successful in producing an atomized liquid, such structures have been relatively expensive to produce and to maintain in the proper operating condition. Accordingly, a great advantage would be obtained if fluid mixing devices, such as used for atomizing liquids, could be manufactured with no moving parts, electrical components or cumbersome bodies within the flow path and yet create sonic vibrations within the mixing device in order further to atomize the liquid charged into the mixing device.

It is a primary object of the present invention to provide a mixing device for dispersing one fluid within another in which the device is relatively simple in construction, is void of minute components which must be accurately machined and positioned within the device and comprises no moving mechanical, electrical or electro-mechanical parts, thereby providing trouble-free and maintenance-free operation of the device as well as relatively inexpensive costs of manufacture.

According to the invention there is provided a mixing device comprising: a first mixing chamber for mixing at least two dissimilar fluids, a first fluid inlet directing fluid longitudinally through said first mixing chamber, a second fluid inlet directing fluid in a vortex about the interior of said first mixing chamber and means to deflect at least a portion of fluid passing from said first fluid inlet into the vortex fluid flow formed within said first mixing chamber.

In the preferred construction later described in detail the mixing device is provided with first and second circular cross section sonic cavitation expansion chambers, a first restriction orifice positioned between the first and second expansion chambers and a second restriction orifice positioned between the second expansion chamber and the flow outlet, the first expansion chamber comprising a first fluid inlet directing a fluid longitudinally through the flow chamber and a second fluid inlet directing fluid in a vortex about the first fluid flow within the first expansion chamber. Positioned downstream and near the first fluid inlet is a deflector plate which deflects a portion of the first fluid flow into the vortex flow so as to entrain the first fluid into the rotating fluid vortex. The mixed fluids are then carried through a compression zone and immediately expanded in the second expansion chamber and again through another compression. In the situation in which a liquid is being atomized by a gas, the plurality of expansions and intermittent compressions of the gas within the liquid vortex produces cavitation of the liquid and the formation of sonic waves which are transmitted through each of the expansion chambers. Accordingly, mixing of dissimilar fluids as well as dissimilar materials such as the atomization of a liquid within a gas stream is efficiently produced before any mixed materials are discharged from the device.

The invention will be further described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a longitudinal sectional view of one form of the atomizer or mixing device of the present invention;

Figure 2 is a transverse sectional view illustrating the fluid inlet which produces the vortex flow in the first expansion chamber of the mixing device taken generally along the line 2—2 of Fig. 1;

Figure 3 is a longitudinal sectional view of a modified form of the mixing device in which the discharge from the second expansion chamber is offset from the longitudinal flow;

Figure 4 is an end view of the modified mixing

device taken along the line 4—4 of Fig. 3;

Figure 5 is a longitudinal sectional view of a mixing device similar to that of Fig. 1 further including inlet ports and exit nozzle structures attached to the mixing device for use in supplying fuel to a combustion zone;

Figure 6 is a transverse sectional view illustrating the fluid inlet which directs fluid into the vortex flow around the first expansion chamber and taken generally along the line 6—6 of Fig. 5;

Figure 7 is a longitudinal sectional view of a mixing device similar to that of Fig. 5 in which the arrows designate the direction of fluid flow;

Figure 8 is a longitudinal sectional view of a mixing device of the present invention for use as an aerator; and

Figure 9 is a transverse sectional view taken generally along the line 9—9 of Fig. 8.

Referring to Figs. 1 and 2, a mixing or atomizing device 10 is of generally cylindrical shape and comprises a first upstream mixing chamber 12, a second downstream mixing chamber 14, a restriction ring 16 which forms a restriction orifice 18 extending between mixing chambers 12 and 14 and a second restriction orifice 20 positioned immediately downstream of mixing chamber 14. Positioned on atomizer 10 immediately upstream of chamber 12 is end cap 22 welded to the upstream end of cylindrical atomizer 10 at weldments 24. A flow inlet 26 directs a first fluid to pass through end cap 22 and into inlet opening 28 which communicates with mixing chamber 12. Fluid flow through inlet 26 and fluid inlet opening 28 is directed through chamber 12 along the longitudinal axis of atomizer 10. A plurality of second fluid inlets 30 are formed transverse to the longitudinal axis of atomizer 10 and communicate with mixing chamber 12 tangentially to inner wall 32 which forms the boundary of cylindrical mixing chamber 12 as can be seen in Fig. 2. Fluid flow through orifices 30 is directed in a vortex about the inner wall 32 of chamber 12 and around the longitudinal flow of fluid entering through inlets 26 and 28. Positioned within the interior of end cap 22 on bottom wall 23 and positioned so as to intercept a portion of the fluid directed through inlet 26 is deflector plate 34 which is slanted at an angle from the vertical intersecting the longitudinal flow of fluid passing from inlet 26. The height to which the deflector plate 34 extends from bottom wall 23 and the angle of inclination of deflector plate 34 to the axis of the atomizer is such as to deflect a portion of the fluid entering atomizer 10 through inlet 26 into the vortex fluid flow formed by the passage of fluid through inlets 30.

In operation as an atomizer, fluid directed through inlet 26 is preferably a gas while the fluid entering mixing chamber 12 through inlets 30 is a liquid which is to be atomized and discharged from atomizer 10 through outlet 36. Referring to Figs. 1 and 7, the atomization of a liquid entering atomizer 10 through inlet 30 can be explained. As stated above, liquid entering chamber 12 through inlet 30 travels in a vortex about the inner wall 32 of chamber 12. Gas entering through inlet 26 is deflected by deflector plate 34 into the vortex flow indicated by reference numeral 38. Preferably, inlets 30 are positioned midway of the length of mixing chamber 12. The liquid vortex flow 38 created in mixing chamber 12 rotates about the incoming gaseous stream and transverse to the longitudinal flow of the gas stream indicated by reference numeral 40. Before the entrance of the gaseous flow 40, the vortex flow 38 is primarily contained between retaining ring 16 and end cap 22 and thus is primarily confined within mixing chamber 12. Due to centrifugal forces generated by the vortex flow, heavier components of the liquid accumulate at or near the boundary layer between the vortex flow 38 and the inner wall 32 of mixing chamber 12 while the lighter components will accumulate toward the innermost layer of the vortex flow or towards the center of mixing chamber 12. Due to the friction forces between the outermost vortex flow and inner wall 32 of mixing chamber 12 and due to the slower rate of movement of liquid at the boundary layer between vortex flow 38 and inner wall 32, shear stresses are created within the vortex flow 38 which produce an increase in the turbulent flow of the rotating liquid and consequently a decrease in the surface tension of liquid at the places of tubulent flow. The atomizing gas enters chamber 12 through inlet 26 whereupon it expands due to the relatively larger size of the diameter of mixing chamber 12 and thus a drop in pressure occurs. The pressure drop causes the lighter components of the rotating liquid to break away in small particles and start mixing with the longitudinal gas flow passing through chamber 12. Further, a portion of the gas stream entering through inlet 26 and deflected by deflector plate 34 is directed into the vortex liquid flow 38 and will be entrained within vortex flow 38 providing a quantity of vapor pockets within the turbulent flow zones of liquid vortex flow 38. Accordingly, the combination of the pressure drop formed by the expanding gas during entrance into mixing chamber 12 and the reduced pressure along the innermost flow of rotating liquid and the introduction of gas into the vortex flow, produces cavitation within the liquid flow. The cavitation of the liquid flow produces bubbles which reach full size and collapse within several microseconds. Because the lifetime of the cavitation is so short, the bubbles are highly evacuated and collapse with great force producing atomization and some vaporization of the surrounding liquid. Further, it is believed that the cavitation forces contribute to the observed vibration of mixing chamber 12 and the production of sonic waves within the interior of chamber 12. The cavitation of the liquid will continue as long as the gaseous flow 40 and liquid vortex flow 38 is such to maintain the fluid at the critical value. Of course, temperature of the liquid and gas streams will also affect the vaporization of the liquid.

Deflector plate 34 is positioned at such an

angle and has such a height as to interrupt gas flow 40 from inlet 26 into basically two flow paths, one flow path contacting the vortex liquid flow 38 and the other passing longitudinally through mixing chamber 12 creating a total fluid flow out of mixing chamber 12. The amount of gas deflected into vortex liquid flow 38 or longitudinally through mixing chamber 12 can be controlled by adjusting the flow of gas entering inlet 26. Decreasing the gas velocity entering inlet 26 causes the gas to strike deflector plate 34 with less force and consequently the drag produced between the gas flow and the surface of deflector plate 34 will be less and consequently the gaseous flow over the surface of deflector plate 34 will be more laminar than turbulent. The substantially laminar flow of gas contacting deflector plate 34 will intrude into the portion of gaseous flow which enters above deflector plate 34, thus bending or forcing a portion of this flow into the vortex liquid flow 38 so as to be entrained therein. Increasing the flow of gas entering inlet 26 increases the drag existing between the gas and the surface of deflector plate 34 thereby causing such gas flow to become turbulent. The turbulent flow of gas bends more sharply down over the edge of deflector plate 34 causing a greater proportion of the inlet gas to flow along the longitudinal axis of chamber 12 and out thereof. The movement of gas flow through mixing chamber 12 can be further affected by the velocity of liquid vortex flow 38. By increasing the vortex rotation velocity, the pressure at the center or innermost layer of the vortex liquid is decreased and is less than the pressure of gas entering mixing chamber 12. Accordingly, the gas is "pulled" through the mixing chamber.

As the liquid continues to rotate about mixing chamber 12, a portion of the atomized liquid flows out of chamber 12 through restriction orifice 18 whereupon the fluid accelerates during passage through restriction orifice 18 and then into a vortex flow within mixing chamber 14. It is believed that as the vortex fluid flow generally indicated by reference numeral 42 spreads over the interior surface 44 of mixing chamber 14 that due to vibrations of the mixing chamber small particles of the liquid at the chamber boundary are thrown from the interior surface of chamber 14 into the vortex flow, whereupon the liquid particles are further atomized and vaporized due to the relatively low pressures formed within the vortex flow and the sonic waves generated in chamber 12 and transmitted throughout the complete interior of atomizer 10.

Passing through restriction orifice 18 formed by retainer ring 16, the gas bubbles formed in the liquid out of chamber 12 collapse or implode due to the relatively higher pressures created within restriction orifice 18. After passing through restriction orifice 18, the gas and atomized liquid enter mixing chamber 16 where again expansion occurs along with a second pressure drop. The decreased pressure further causes atomization and vaporization of the liquid whereupon the atomized liquid is compressed a second time through restriction orifice 20 which causes any gas bubbles in this zone to collapse or implode.

The gas bubbles carried through restriction orifices 18 and 20 are covered with a thin film of liquid. As the gas bubbles implode, the liquid film breaks down and thus further atomizes the liquid. The implosion of the gas bubbles is believed to also take part in the formation of the sonic waves generated within mixing chambers 12 and 14. The sonic waves are reflected from the interior surfaces of the chambers into the center thereof which further affects the particles size of the liquid being atomized. Likewise, the alternating deceleration and acceleration of fluid as it passes from the inlets to the mixing chambers and through the restriction orifices also aids in the production of sonic waves within the mixing chambers 12 and 14. The sonic vibration frequency can be varied by changing the gas or liquid flow velocity and gas and liquid temperatures. The range of sonic frequency adjustment may also be changed by increasing or decreasing the mixing chamber size which attenuates the sonic vibrations. Attenuation of the sonic vibrations will vary the particle size during atomization and the amount of liquid vaporization.

Most of the liquid which flows into mixing chamber 14 from chamber 12 is already in an atomized condition and thus the liquid is further rapidly reduced in particle size in chamber 14. Similarly, a significant portion of the liquid is vaporized within chamber 14. Atomized liquid is then passed from atomizer 10 through outlet 36. While the operation of atomizer 10 has been described as the atomization of a liquid within a gas, other dissimilar fluids may be mixed including powdered solids which are to be entrained within a gas stream, powdered solids which are to be entrained within a liquid stream, dissimilar gases and even dissimilar liquids.

Figures 3 and 4 illustrate an atomizer or mixing device 46 which is substantially equivalent to atomizer 10 and includes first and second expansion chambers 48 and 50, respectively, end cap 52 which is welded upstream of mixing chamber 48 and includes an inlet 54 and inlet flow passage 56 into mixing chamber 48. Mixing device 46 further includes a deflector plate 58 positioned in an equivalent manner as deflector plate 34 in atomizer 10. Inlets 60 produce a vortex flow of fluid directed through such inlets into mixing chamber 48. A restriction orifice 62 separates mixing chambers 48 and 50. The difference between mixing device 46 and atomizer 10 is the location of restriction orifice 64 which is placed downstream of mixing chamber 50. As can be seen, restriction orifice 64 is offset from the longitudinal flow of fluid directed through mixing device 46 from inlet 54. Accordingly, a solid body in the form of interior wall 66 of mixing chamber 50 is placed in direct contact with and downstream of the fluid flow passing through mixing chamber 50. Further, the diameter of restriction orifice 64 is less than the diameter of

restriction orifice 20 in atomizer 10. Sonic waves generated within mixing device 46 are reflected from surface 66 back into mixing chamber 50 and restriction orifice 62. The reverberation of the sonic waves causes further atomization or mixing of fluids within restriction orifice 66 and thus even greater mixing within mixing chamber 50. If the vortex fluid is a liquid, a greater proportion of the output through restriction orifice 64 and outlet 68 will be vapor than is achieved in atomizer 10 in which restriction orifice 20 and outlet 36 are in line with the longitudinal gas flow.

In Fig. 5 is shown an atomizer or mixing device 70 which is in the form of an igniter for a large combustion chamber used to combust a fuel such as pulverized coal or heavy oil in power plant operations or similar applications. Mixing device 70 is similar to atomizer 10 and includes upstream and downstream expansion chambers 72 and 74, respectively, restriction orifices 76 and 78, fluid inlet 80 for passage of fluid longitudinally through mixing device 70, a single fluid orifice 82 directing fluid into mixing chamber 72 in a vortex path about the interior of mixing chamber 72, end cap 84 containing inlet 80 and supporting deflector plate 86. Fluid such as a gas entering inlet 80 can be supplied from a source (not shown) which communicates with inlet adapter 88 welded to end cap 84 at weldments 90. The threaded end 92 of inlet adapter 88 can be used for attachment to a source of fluid. A fluid supplied to inlet 82 and atomized by a gas supplied through inlet 80 will pass from restriction orifice 78 through outlet 94 and into the interior of a hollow extension tube 96 which is threaded into a mounting adapter 98 by means of respective threads 100 and 102 contained on extension tube 96 and adapter 98, respectively. Mounting adapter 98 can be fixed to mixing chamber 70 by means of weldments 104. Atomized fluid passing through extension tube 96 is discharged through a plurality of orifices 106 placed within end cap 108 and into the combustion chamber (not shown) of the power plant. End cap 108 can be threaded onto the end of extension tube 96 by means of threaded surfaces generally indicated by reference numeral 110. In the situation in which a liquid fuel is atomized, some difficulty might be encountered by condensation of the atomized liquid into larger particles during travel through an excessively long extension tube 96. However, it has been found that a mixing device equivalent to mixing device 70 illustrated in Fig. 5 performs satisfactorily with an extension tube 96 of approximately 14 feet ($4\frac{1}{4}$ metres) wherein the atomized liquid passed through a lighter assembly and wind box extended into the combustion chamber. Preheating of combustion air that flows through the wind box can alleviate a problem of relatively large liquid particles. Prehating combustion air is conventional in most large boiler operations. Due to the structure of atomizer 70 the greatly atomized liquid fuel including vaporized fuel produces a large flame at higher temperatures with less fuel than can be obtained with present state of the art fuel igniters and without their attendant problems. Further, in the present construction, increased nebulizing of the atomized liquid passing through extension tube 96 can be accomplished by passing preheated combustion air around the extension tube or by radiant heat from an encasing ceramic heater. Because the liquid has already been atomized and nebulized before it is discharged from end cap 108, a wide variety of end cap configurations may be utilized to give any type of log or flame pattern.

Typical mechanical atomizers produce a liquid particles size which is so large that approximately 30% to even 40% of the liquid fuel is carried out of the flame zone before the fuel has time to diffuse with oxygen and combust. Prior art steam or air atomizers improve combustion by exposing more liquid fuel surface to diffuse with the oxygen, but still do not give complete combustion unless used with some means of providing turbulence. Further, presently used sonic atomizers produce uniform particles sizes that will give immediate complete combustion with resulting small flame or if they are adjusted to produce larger particle sizes to create a flame of sufficient size and temperature, they will have the problems of combustion set forth with air or steam atomizers that atomize by impingement inside or just outside the nozzle. The atomized fuel provided by use of the present construction provides instant ignition because a large proportion of the liquid is in a gaseous form already diffused with oxygen. Since the burning period of a fuel particle is approximately proportional to the square of the diameter of the particle, and because the present construction can be adjusted to produce fuel vapor and atomized fuel particles of varying size depending upon the liquid fuel and entraining gas throughput, a hotter flame of larger size with complete combustion of the fuel with colder combustion air can be obtained than found in devices presently in use. Since a hotter, larger flame with consumption of less fuel can be obtained with the present atomizer or mixing device considerable savings of consumer fuel with more efficient and safe ignition of other fuels, such as pulverized coal or heavy oil, can be realized. In mixing device 70, adapter 98 is mounted externally of the combustion chamber. The operation and efficiency of mixing device 70 allows the device to be placed externally of the combustion zone and thus it has the advantage of operating in a relatively cool environment and is therefore not subjected to internal caking or build-up of deposits which would adversely affect the operation of the mixing device, decreasing the output of fine atomized or nebulized fuel particles and thus decreasing combustion efficiency.

Mixing device 70 can be used as a burner for many different applications. For example, mixing device 70 may be used singularly as a main burner for building hot water boilers or a plurality of devices 70 may be grouped as necessary for small to medium range steam generating boilers or as a burner for liquid waste. Of course, it is to be

understood that these are only a partial listing of possible applications and are not to be taken as limiting or restricting the applications of the mixing devices which are structured embodying the invention.

A typical mixing device of the present invention, such as mixing device 70 illustrated in Fig. 5, can be constructed of metal, preferably stainless steel with the following dimensions: Gas inlet adapter 88, formed of 1/2 inch (1.27 cm) tubing welded to end cap 84 which has dimensions of 1-3/4 inches (4.45 cm) outside diameter and 1-3/8 inches (3.5 cm) inside diameter and is approximately 0.65 inch (1.65 cm) deep with a wall thickness of 0.4 inch (1 cm); deflector plate 86, 1/8 inch (0.32 cm) thick and shaped to fit the lower surface of end cap 84, preferably welded at a 50° angle from the bottom surface of end cap 84 and of a height approximately 0.725 inch (1.84 cm) although devices with deflector plates mounted at slightly different angles and heights can be operated satisfactorily; inlet 80, approximately 1/4 inch (0.64 cm) in diameter; mixing chamber 72, approximately 1.8 inches (4.6 cm) long, an outside diameter of 2.25 inches (5.7 cm), an inside diameter of 1.675 inches (4.25 cm) with a 0.35 inch (0.89 cm) wall thickness; restriction orifice 76, approximately 0.25 inches (0.64 cm) long, an inside diameter of 1.175 inches (2.98 cm) and is, of course, positioned midway between mixing chambers 72 and 74; fluid inlet 82, 0.125 inch (0.32 cm) in diameter and fluid inlet connector 112 which is welded and centered over inlet 82, 1/4 inch (0.64 cm) stainless steel pipe; adapter 98, welded to the discharge end of mixing device 70, approximately 2-3/8 inches (6 cm) long, an outside diameter of 1.73 inches (4.39 cm); extension tube 96, 1/2 inch (1.27 cm) tubing with a length of approximately 10 feet (3.05 metres); orifices 106, 0.1 inch (0.25 cm) in diameter and drilled at 45° from centre. Of course, other dimensions may be successfully utilized and as such the preceding values are not intended to limit the invention in any way.

In Fig. 8, a mixing device generally indicated by reference numeral 114 is in the form of an aerator. The operation of aerator 114 involves the same principles as previously described for atomizer 10 and mixing device 70. The modifications are primarily in the manner in which the gas source is brought into upstream mixing chamber 116 and the relatively smaller diameter of downstream mixing chamber 118 with respect to mixing chamber 116. Further, fluid flow from mixing chamber 118 is converged into second restriction orifice 120. Restriction orifice 122 positioned between mixing chambers 116 and 118 is equivalent to such restricting orifices of the previous embodiments. Aerator 114 is provided with an end cap 124 which is significantly different from end caps 22 and 84 of atomizer 10 and mixing devices 70, respectively. End cap 124 is a solid block which comprises an inlet 126 communicating with a gas source and a plurality of orifice jets 128 communicating with inlet 126 and mixing chamber 116. Orifice jets 128 are angled so as to direct gas flow into the rotating vortex fluid flow entering through inlets 130. Inlets 130 receive liquid through inlet adapters 132 which are centered over inlet orifices 130. Mixing chamber 118 is also provided with a plurality of vortex fluid inlet jets 134 which are supplied via inlet adapters 136. The number of inlet orifices 134 directing fluid into mixing chamber 118 should be at least double the amount of fluid jets 130 communicating with mixing chamber 116. Due to the reduced size of chamber 118, the vortex fluid in chamber 118 will be moving at a faster speed than the vortex fluid flow in chamber 116. The converging downstream end 138 of mixing chamber 118 will speed the vortex flow from chamber 118 through second restriction orifice 120 and through outlet 140. In operation, gas enters inlet 126 and is directed through the plurality of inlet jets 128 into the fluid vortex flow which is formed by fluid entering chamber 116 through inlet jets 130. Gas directed into the vortex flow will initiate cavitation of the vortex fluid flow. It is believed that the faster flow of vortex fluid in chamber 118 and the converged end 138 of chamber 118 will cause total fluid flow along the longitudinal axis of aerator 114 to be faster through chamber 118 than chamber 116. It is also believed that the imbalance of vortex fluid flow speeds between chambers 116 and 118 will cause a substantial difference of pressure across restriction orifice 122 as well as a lesser pressure in chamber 118 than in chamber 116. The pressure drop within restriction orifice 122 will cause more vapor bubbles to be evacuated in the fluid, thus producing more sonic waves throughout the interior of aerator 114. These sonic waves create more turbulent discontinuities in a total fluid flow, thus causing more cavitation of the vortex fluid within each chamber 116 and 118.

The present invention, regardless of whether it is used as a mixer, atomizer or aerator, produced fluid vibrations ranging from the sonic into the high ultrasonic. The physical dimensions of the particular components determine the range of sonic frequencies produced. The frequencies produced by the device can be further controlled by adjusting either or both of the fluid inlet pressures. The frequencies of vibration may also be determined to some extent by controlling fluid temperatures. Uniform mixing, atomization, nebulization, aeration, etc., can be successively produced by the present invention at substantially any range of fluid pressures provided the mixing chambers and the restriction orifices are sized to provide sufficient time for the fluids to interact within each of the chambers. It is critical that fluid pressure is sufficient to sustain the vortex flow. Vortex flow can be obtained by relatively lower pressures by increasing the number of inlet jets entering the mixing chamber. Longitudinal fluid flow through the mixing device must be provided at pressures which will sustain the total fluid flow through the chambers and through the outlet of

the device. It has been found that the smaller the longitudinal fluid pressure, the greater will be the degree of mixing, atomizing, etc.

CLAIMS

1. A mixing device comprising: a first mixing chamber for mixing at least two dissimilar fluids, a first fluid inlet directing fluid longitudinally through said first mixing chamber, a second fluid inlet directing fluid in a vortex about the interior of said first mixing chamber and means to deflect at least a portion of fluid passing from said first fluid inlet into the vortex fluid flow formed within said first mixing chamber.

2. A mixing device according to claim 1, wherein a second mixing chamber is positioned downstream from the first mixing chamber and is in communication with said first chamber by means of a restriction orifice of smaller cross-sectional area than said first and second mixing chambers and a second restriction orifice is positioned downstream from and in communication with said second mixing chamber.

3. A mixing device according to claim 2, wherein said first and second mixing chambers and said first and second restriction orifices are of a circular cross section.

4. A mixing device according to claim 2 or 3, wherein said second fluid inlet comprises a plurality of inlets directing fluid at spaced locations into the interior of said second chamber, each of said fluid inlets entering said second chamber tangentially of said circular shaped second mixing chamber.

5. A mixing device according to any one of claims 2 to 4, having a flow outlet positioned downstream of said second restriction orifice.

6. A mixing device according to claim 5, wherein said flow outlet is an elongated extension tube attached at said second restriction orifice.

7. A mixing device according to claim 2 or 3, wherein said first fluid inlet comprises a plurality of fluid inlets communicating with said first mixing chamber, a portion of said plurality of fluid inlets directing fluid into the vortex fluid flow.

8. A mixing device according to claim 7, wherein a third fluid inlet is provided for directing fluid into said second mixing chamber in the form of a vortex fluid flow within said second chamber.

9. A mixing device according to claim 8, wherein said second fluid inlet and said third fluid inlet comprise a plurality of fluid inlets directing fluid into the respective mixing chambers.

10. A mixing device according to any one of claims 1 to 6, wherein said means to direct a portion of said fluid flow from said first inlet into the vortex flow comprises a deflector plate positioned adjacent said first fluid inlet.

11. Mixing devices constructed and arranged to operate substantially as herein described with reference to or as illustrated in the accompanying drawings.

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